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# **London Underground Guidelines on Ground Movement Due to Tunnelling and Deep Excavations**

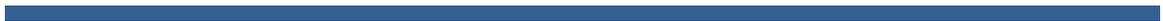
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## **Non-Technical Summary**

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**Transport for London**  
**London Underground**





**LONDON UNDERGROUND LIMITED**  
**GROUND MOVEMENT GUIDELINES**

**1. Introduction**

- 1.1 This guidance applies to all new London Underground Limited (LUL) infrastructure schemes promoted through the Transport and Works Act 1992 (TWA Order) or other parliamentary enactments and orders.
  - 1.2 A number of major tunnelling projects have been undertaken in London in recent years including the London Water Ring Main, Heathrow Express, Jubilee Line Extension, extensions to the Docklands Light Railway, Channel Tunnel Rail Link and the Heathrow Express and Piccadilly Line extensions to Heathrow Terminal 5. As a result, there is extensive experience of how the ground behaves when tunnels are constructed and how to minimise the effects on the buildings above.
  - 1.3 The construction of tunnels, station boxes and shafts are likely to lead to movement of the ground. The amount of movement will depend on a number of factors including the depth and volume of the works below ground, soil conditions and the presence and nature of building foundations. The amount of movement will vary across the area affected and for some buildings the magnitude of movement varies across the building. This is known as differential settlement. If there is no differential settlement then the building is very unlikely to be damaged, whereas differential settlement has the potential to damage buildings and other infrastructure, including utilities. If damage were to occur, it could range from small internal cracks in plaster to effects on the structural integrity of the building, although in most cases there is no discernible effect on the structure itself.
  - 1.4 LUL, as far as reasonably practicable, will take all steps to minimise ground movement damage and adopt industry good practice. Additional measures may also
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be used to reduce the risk of damage to buildings, depending on the nature of the assessed damage risk. These include direct works to the building, such as

underpinning or strengthening the foundations, as well as ground treatment around and beneath the building.

- 1.5 As a consequence, LUL have established a minimum requirement process to assess the risk of potential ground movement and to manage the effects on neighbouring buildings and structures.
- 1.6 LUL will undertake an assessment of the potential ground movement around the works or along the route of the railway and identify all buildings within the zone affected by ground movement that may be at risk of damage. Depending on the level of risk either no action will be required, buildings will be monitored during construction, or special protective measures will be implemented to protect the buildings.
- 1.7 This paper covers the following issues:
  - a) Method of assessing ground movement and associated risk
  - b) Monitoring.
  - c) Protective works.
  - d) Defects surveys.
  - e) Repairs.
  - f) Listed buildings.

## 2. Ground Movement Assessments

- 2.1 Buildings which may be affected by excavations carried out by LUL are assessed using a three phase process similar to that developed on other projects including the
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Jubilee line extension and, the Channel Tunnel Rail Link. This assessment consists of one, two or three phases as described below.

- 2.2 The objective of this assessment is to determine the level of damage risk to buildings. The results will enable the planning of ground movement monitoring and other risk mitigation measures such as defect surveys. The process described here is

designed to identify those existing buildings at greater risk and focus subsequent work appropriately.

### 2.3 PHASE 1

- 2.3.1 The Phase 1 assessment assumes “green-field” site conditions. This means that the effect of building foundations and other infrastructure is ignored for the purposes of the assessment on the pattern of movement.
- 2.3.2 For bored tunnels the settlement predictions for “green-field” site conditions are produced based on empirically validated methods such as those described by O’Reilly and New (1982) and Attewell and Woodman (1982) using parameters for ground loss determined from case histories and taking into account the method of tunnelling and ground conditions.
- 2.3.3 For excavations comprising deep shafts, boxes and retained cuttings, assessments will be undertaken using models validated by empirical data based on case studies of similar excavations.
- 2.3.4 Where the predicted settlement from bored tunnels and from the



excavations referred to above is less than 10mm buildings are not subject to further assessment. Those for which predicted movement is 10mm or more, are subject to a Phase 2 assessment.

## 2.4 PHASE 2

- 2.4.1 In Phase 2 the movement predicted for “green-field” conditions is imposed on buildings. It is initially assumed that buildings behave completely flexibly and their own stiffness has no influence on the movement behaviour. This is a conservative assumption as, in reality, a building’s structure and foundations will modify the ground movement effects and limit the development of horizontal strain, reducing the potential for damage.
  - 2.4.2 The potential for damage in this assessment is defined using the procedures described by Burland (1995) and Mair et al (1996). Each building is placed into one of six risk categories (numbered 0-5) by reference to maximum tensile strain as described in column 2 of Table 1. This classification is conservative as it assumes a simple brick masonry construction, whereas other forms of construction, such as framed buildings, may be more robust.
  - 2.4.3 If a building cannot be satisfactorily represented using the procedures described by Burland and Mair (as above) it will automatically qualify for a Phase 3 assessment.
  - 2.4.4 Buildings assessed to be in risk category 0, 1 or 2 after the Phase 2 assessment are not subject to further assessment.
  - 2.4.5 All buildings which are placed in risk category 3 or above in the Phase 2 assessment are subject to a Phase 3 assessment.
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2.4.6 Any building which has been subject to a Phase 2 assessment but which does not qualify for further assessment under paragraph 2.4.4 above is nonetheless subject to a Phase 3 assessment if:

- (a) it is on shallow foundations and is within a distance from a retained cutting, shaft or box equal to the excavated depth of superficial deposits. In this context, superficial deposits are taken to be soils such as Made Ground, Alluvium or Terrace Gravels,
- (b) it is a listed building, or
- (c) London Underground Limited considers that for some other reason the determination of whether protective works for the building are required, or the form that such protective works should take, requires further assessment in Phase 3 to be undertaken.

### 2.5 PHASE 3

2.5.1 In Phase 3 of the assessment procedure, each building is considered individually. This assessment will generally involve the development of a building specific detail model rather than the more generic model forms used in Phase 2 .

2.5.2 The Phase 3 assessment commonly consists of several sub-steps (referred to as “iterations”), each refining the building and tunnel model to a higher degree. In this Phase both the strain developing within the building and the applicability of the standard risk categories (which are based on masonry structures) are reappraised. In the first Iteration the model may be closely based on that used in the Phase 2 assessment. If necessary, the tunnel-excavation soil-building interaction problem is modelled numerically. The



approach is to use simplified assumptions in the first instance and refine the analysis to see if a more accurate approach results in the risk of damage reducing to an acceptable level.

2.5.3 A structural survey will be undertaken to determine the structural form and condition of the building where reasonably necessary for the assessment. In every case where a building is subject to a phase 3 assessment, a desktop structural appraisal by a Qualified Structural Engineer will be carried out for the purpose of confirming the likely structural behaviour and determining whether such a structural survey is necessary.

2.5.4 As a result of the Phase 3 assessment, the risk category of the building is reassessed and the requirement for any protective works is established. The design and implementation of any protective works and associated specialised monitoring will be developed based on these results. These matters will be described in the assessment report for the building.

## 2.6 OTHER MATTERS

2.6.1 Building owners may request a copy of the assessment report which the engineer will supply and discuss with the owners if the building has progressed to at least Phase 2 of the assessment process.

## 3. Monitoring

3.1 Requirements for monitoring will be confirmed by the assessment report. Generally, all buildings in risk category 3 or above will be monitored during tunnel construction. Monitoring buildings in category 2 and below will be covered by the general surface monitoring. If necessary, modifications will be made to the tunnelling method and/ or



protective works taken to safeguard the building. In addition to this, general monitoring will be carried out over the whole area affected by ground movement.

- 3.2 Where practicable, it is proposed to carry out background monitoring to establish seasonal trends, with building specific monitoring commencing at least 1 month prior to commencement of the works. Monitoring will continue until all potentially damaging movement due to the works has ceased. This is defined as when the rate of movement is less than or equal to 2mm/annum.
- 3.3 Generally, construction phase monitoring will consist of precisely surveying the outside of the buildings. Occasionally, dependent on structure size and extent of movement, precise levelling will take place inside structures. Other forms of monitoring may also be employed, which will be determined on a case by case basis.

#### 4. Protective Measures

- 4.1 LUL, as far as reasonably practicable, will take all steps to minimise the damage from ground movement. Through industry good practice additional measures may also be used to reduce the risk of damage to buildings, depending on the nature of the assessed damage risk. These might include special tunnelling

methods, ground treatment around and beneath the building, as well as direct works on the building. These three categories are described in more detail below:

- *Minimisation of ground movement at source.* A range of measures can be used during tunnelling and excavation works to reduce the magnitude of ground movements generated. The detail of the measures will depend on the type of construction involved. These include all actions taken from within the



tunnel, shaft or box excavation during its construction to reduce the ground movements generated at source.

- *Ground treatment measures.* These comprise methods of reducing or modifying the ground movements generated by tunnelling/box excavation by improving or changing the engineering response of the ground. Categories of ground treatment include: compensation grouting, which involves injecting grout into the ground above the tunnel to compensate for the ground loss at the tunnel face; permeation or jet grouting which involves the creation of stiffer ground to reduce movement; and control of ground water to avoid changes which could potentially cause ground movement.

- *Structural measures.* These methods reduce the impact of ground movements by increasing the capacity of a building to resist, modify or accommodate those movements. Typical measures would include underpinning or jacking. Underpinning involves the introduction of a new strengthened foundation system to a building or structure potentially affected by settlement. Jacking is a technique whereby a system is introduced between the building and its existing foundations to compensate for any movement.

4.2 These mitigation measures are tried and tested. They have proven effective in mitigating potential ground movement effects on other major projects involving a similar scale and complexity of tunnelling and excavation. For example see Mair (2001).

## 5. Defect Survey

5.1 Defect surveys will be undertaken on all buildings predicted to experience 10mm or more of movement in the assessment carried out under phase 2 above with respect

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to LUL excavations. These surveys will record the condition of the properties immediately prior to tunnel construction commencing in an area. They are a written and photographic record of existing cracking and the general structural condition of the building. The surveys will be carried out by a chartered building surveyor commissioned by LUL at LUL's cost but in joint names with the building owner and any other persons as London Underground Limited may determine. Owners are free to commission their own independent survey but this will be at their own cost since the project survey is an objective survey/record of pre existing defects and is not intended to draw any conclusions as to the cause.

- 5.2 An electronic or hard copy of the report will be available to the owner on request.
- 5.3 If, following the construction of the tunnels in the vicinity of the building, the owner responsible for repairing a building reasonably believes damage has occurred then London Underground Limited should be notified in writing within 6 years from the date on which the cause of the damage accrued.<sup>1</sup> This would normally be:-
- the date of entry onto the affected owners land to construct the works or
  - if no land is acquired then the date the excavation commenced which reputedly caused the damage to the property.

A second survey will then be undertaken by London Underground Limited's surveyor to record changes from the first survey. The owner may request their own surveyor to attend when the second survey is undertaken and to comment on the draft survey report produced on behalf of London Underground Limited.

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<sup>1</sup> Section 9(1) of the Limitation Act 1980



Reasonable professional fees (agreed in advance) incurred by the owner in making a successful claim will be reimbursed by London Underground Limited.

- 5.4 A comparison of the first and second surveys may form the basis of any claim. London Underground Limited may appoint a loss adjuster to assess the extent to which the damage has been caused by the works and agree the remedial works to be undertaken at the expense of London Underground Limited.

## **6. Repairs**

- 6.1 London Underground Limited will reimburse property owners for any reasonable cost they incur in remedying material physical damage arising from ground movement caused by the authorised works, provided:

- the damage was caused by London Underground Limited's works,
- the owner gives not less than 28 days notice in writing to London Underground Limited of the proposal to carry out the repair work,
- the owner takes reasonable steps to obtain 3 competitive quotes for the repairs beforehand where required by London Underground Limited, and
- any claim is made before the end of the 6 year period referred to in paragraph 5.3 above.

- 6.2 London Underground Limited may, on receiving the advanced notice of the proposal to carry out the repair work, elect to undertake the repair work itself with the consent of the property owner.

- 6.3 If there are any pre-existing defects which have worsened as a result of the works then the recoverable loss will be limited to the additional cost of repair over and



above that which would have been required to deal with pre-existing defects.

- 6.4 If it can be demonstrated that the undertaking to assess the compensation claim based on the reasonable cost of repairs does not compensate the claimant fully for the reduction in value of his interest in the building then this does not prejudice a further claim for compensation in accordance with the national compensation code within the normal limitation period applying to such claims.

## 7. Listed Buildings

- 7.1 All listed buildings are subject to the provisions of this paper as set out in Sections 1 to 6 above. In particular, as stated in paragraph 2.6.4, all listed buildings (with movement of 10mm or more) automatically qualify for a detailed assessment at Phase 3.
- 7.2 During Phase 3 assessment, the heritage value of a listed building is considered by reviewing the sensitivity of the building structure and of any particular features against the risk category assigned in Phase 2. The heritage assessment examines the following:
- (a) the sensitivity of the building to ground movements and its ability to tolerate movement without significant distress. The potential for interaction with adjacent buildings is also considered. A score within the range of 0-2 will be allocated to the building in accordance with the criteria set out in Table 2.
  - (b) the sensitivity to movement of particular features within the building and how they might respond to ground movements. A score within the range of 0-2 will be allocated to the building in accordance with the criteria set out in Table 2.
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- 7.3 In addition, a score corresponding to the Phase 2 assessment risk category within the range of 0-5 as set out in Table 1 is allocated to the building.
- 7.4 The scores for each of the three categories (7.2 (a), 7.2 (b) and 7.3) are added together to inform the decision making process. In general, listed buildings which score a total of 3 or higher are subject to further assessment as part of the Phase 3 iterative process. Buildings which score a total of 2 or less are predicted to suffer a degree of damage which will be easily repairable using standard conservation based techniques and hence no protective measures for the building's particular features are required. However, ultimately the professional judgement of engineering and historic building specialists will be used to determine whether additional analysis is required. Upon conclusion of the Phase 3 iterations, a final composite score will be derived by adding the risk category of the building (ignoring the fact that it is a listed building) assessed in accordance with the normal principles of Phase 3 assessment, to the combined final scores for each of the two additional sensitivities referred to in paragraph 7.2(a) and (b) in accordance with Table 2, and this final composite score will constitute the risk category of the listed building for the purposes of paragraph 2.5.4 above.
- 7.5 The relevant local authority will be consulted on the results of the listed building assessment reports for listed buildings subject to Phase 3 assessment and the proposals for protective measures, if any are required. English Heritage will also be consulted in relation to listed buildings subject to Phase 3 assessment where they would normally be notified or consulted on applications for planning permission or listed building consent (as set out in DETR and DCMS Circular 1/01).
- 7.6 When considering the need and type of protective measures, due regard will be given to the sensitivity of the particular features of the building which are of special architectural or historic interest and the sensitivity of the structure of the building to ground movement. Where the assessment highlights potential damage to the
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features of the building which it will be difficult or impossible to repair and/or if that damage will have a significant effect on its heritage value, the assessment may recommend appropriate measures to safeguard those features either in-situ or by temporary removal and storage off-site if those with relevant interest(s) in the building agree.

- 7.7 The method for monitoring any listed buildings will be determined upon the basis of the results of the assessment process.
- 7.8 If repair works are necessary, the arrangements for implementation or for the reimbursement referred to in section 6 above will apply. Reimbursable costs will include the costs of any necessary expert advice from a person suitably qualified to advise on heritage issues. The carrying out of the repair works will however require the consent of those with relevant interest(s) in the building.

## **8. Transport for London**

These guidelines may in future become adopted as a policy by Transport for London for a future process to assess the risk of potential ground movement and to manage the effects on neighbouring buildings and structures in relation to transport tunnelling and deep excavation projects.

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### **Definitions:-**



**Transport & Works Order  
(TWA Order)**

An Order under the Transport and Works Act 1992 granting powers an authority to construct transport infrastructure for the purpose of transport services.

**Qualified Structural Engineer**

Individual who is a chartered engineer with experience in the assessment of ground movement

**National Compensation Code**

The Code, which originated in the 19<sup>th</sup> century, being an amalgamation of numerous Acts of Parliament, amendments, consolidations and legal precedents. The main Acts of Parliament comprising the compensation code are as follows:-

- (a) The Land Compensation Act 1961
- (b) The Compulsory Purchase Act 1965
- (c) The Land Compensation Act 1973
- (d) The Acquisition of Land Act 1981
- (e) The Town and Country Planning Act 1990
- (f) The Planning and Compensation Act 1991
- (g) The Transport and Works Act 1992

These Acts set out rules to be applied when assessing compensation and are designed to reflect the loss that is sustained by landowners as a direct result of the relevant works.

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### REFERENCES

Attewell, P.B., and Woodman, J.P. (1982). Predicting the dynamics of ground settlement and its derivatives caused by tunnelling in soil. *Ground Engineering, Vol. 15, No 8, pp. 13-22 and 36.*

Burland, J.B., Broms, B.B., & de Mello, V.F.B. (1977). Behaviour of foundations and structures. *Pages 495-546 of: Proc. 9th Int. Conf. Soil Mech. And Found. Eng., vol. 2.*

Burland, J.B. (1995). Assessment of risk of damage to buildings due to tunnelling and excavation. *Invited Special Lecture: In: 1st Int. Conf. On Earthquake Geotech. Engineering, IS Tokyo '95.*

Harris, D. I. & Franzius, J. N. (2005). Settlement assessment for running tunnels – a generic approach. *Proc. International Symposium of Geotech. Aspects of Underground Construction in Soft Ground, Amsterdam, 2005*

Mair, R.J., Taylor, R.N. and Burland, J.B. (1996). Prediction of ground movements and assessment of risk of building damage due to bored tunnelling. *In: Proc. Of the Int. Symp. On Geotech. Aspects of Underground Construction in Soft Ground, 713-718, Balkema, Rotterdam.*

O'Reilly, M.P. and New, B.M. (1982). Settlements above tunnels in the United Kingdom – their magnitude and prediction. *Tunnelling '82. Ed Jones, M.J. pp 173-181. London, IMM.*

Rankin, W.J. (1988). Ground movements resulting from urban tunnelling: predictions and effects. *Pages 79-92 of: Engineering geology of underground movements. The Geological Society, London.*

**TABLE 1**  
**Building Damage Category Classification**

Building Damage Classification <sup>1</sup>				
1	2	3	4	5
Risk Category	Max Tensile Strain %	Description of Degree of Damage	Description of Typical Damage and Likely Form of Repair for Typical Masonry buildings	Approx Crack Width (mm)
0	0.05 or less	Negligible	Hairline cracks.	
1	More than 0.05 and not exceeding 0.075	Very Slight	Fine cracks easily treated during normal redecorations. Perhaps isolated slight fracture in building. Cracks in exterior brickwork visible upon close inspection.	0.1 to 1
2	More than 0.075 and not exceeding 0.15	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible; some repointing may be required for weather-tightness. Doors and windows may stick slightly.	1 to 5
3	More than 0.15 and not exceeding 0.3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Repointing and possibly replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather tightness often impaired.	5 to 15 or a number of cracks greater than 3
4	More than 0.3	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks
5		Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require	Usually greater than 25 but



			shoring. Windows broken by distortion. Danger of instability.	depends on number of cracks
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**TABLE 2**  
**Scoring for Sensitivity Assessment of Listed Buildings**

Score	Criteria	
	Sensitivity of the structure to ground movements and interaction with adjacent buildings	Sensitivity to movement of particular features within the building
0	Masonry building with lime mortar not surrounded by other buildings. Uniform facades with no particular large openings.	No particular sensitive features
1	Buildings of delicate structural form or buildings sandwiched between modern framed buildings which are much stiffer, perhaps with one or more significant openings.	Brittle finishes, e.g. faience or tight-jointed stonework, which are susceptible to small movements and difficult to repair.
2	Buildings which, by their structural form, will tend to concentrate all their movements in one location.	Finishes which if damaged will have a significant effect on the heritage of the building, e.g. cracks through frescos.

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**Notes**



1. Table 1 is based on the work of Burland et al (1977) and includes typical maximum tensile strains for the various damage risk categories (column 2) used in Phase 2 and Phase 3 settlement analysis.

2. Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.

## **LUL guidelines on ground movement due to tunnelling and deep excavations**

### **Non-Technical Summary**

#### **Introduction**

A number of major tunnelling and deep excavation projects have been undertaken in London in recent years including the London Water Ring Main, Heathrow Express, the Jubilee Line Extension, extensions to the Docklands Light Railway, Channel Tunnel Rail Link and the Heathrow Express and Piccadilly Line extensions to Heathrow Terminal 5. As a result, there is extensive experience of how the ground behaves when tunnels and deep excavations are constructed and how to minimise the effects on the buildings above.

London Underground Ltd (LUL) have established guidelines to meet the risk of potential ground movement and to manage the effects on neighbouring buildings. This paper provides a non-technical summary of the guidelines as follows:-

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#### **Ground movement risk**

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All subsurface excavations may give rise to ground movements. These movements commonly include settlement. This ground movement has the potential to damage buildings and other infrastructure including utilities. Where such damage occurs it is most commonly apparent as minor cracking to building finishes although more significant structural effects are possible. In practice the vast majority of recent tunnelling and deep excavation work in London has resulted in little or no discernible effect at the surface. This has been achieved through the use of a range of measures to limit ground movement at source and mitigate its effects on existing infrastructure.

### Assessment and mitigation measures

In order to control the risk of damage, assessments will be undertaken for existing infrastructure including buildings within the zone potentially affected by ground movement. This is a routine part of the tunnel and infrastructure design process and involves using well established methods to assess the need for any mitigation measures.

The assessments will use a three stage process similar to that applied on other recent projects. This process aims to identify systematically any infrastructure which is at significant damage risk and to quantify the level of that risk. Infrastructure at very low risk is also identified and discounted from more detailed assessment. The assessment stages are as follows:

- *Stage 1: Prediction of greenfield movement contours.*

Calculations are undertaken to identify the extent of the area where movement may occur due to the works. The results are presented as plan drawings showing contours of worst case ground movement overlaid on the existing infrastructure. This assessment represents the worst-case as the effect of buildings on the pattern of ground movement is ignored.

- *Stage 2: Initial assessment.*

An analysis using simple engineering models to determine the degree of damage risk for buildings and other infrastructure within the area identified as subject to significant settlement in Stage 1.

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- *Stage 3: detailed assessment.*



Detailed analysis of buildings or other infrastructure identified as being at risk of moderate damage or worse in Stage 2.

In areas where significant damage risk is predicted, appropriate measures will be taken to limit the effects.

Surveys will be undertaken and, where appropriate, buildings will be monitored before, during and for a period after the construction takes place.

Depending on the findings of the assessment process the following types of mitigation measures may be undertaken during construction to protect buildings from the effects of ground movement.

- *Minimisation of ground movement at source.* A range of measures can be used during tunnelling and excavation works to reduce the magnitude of ground movements generated. The detail of the measures will depend on the type of construction involved. These include all actions taken from within the tunnel, shaft or box excavation during its construction to reduce the ground movements generated at source.
- *Ground treatment measures.* These comprise methods of reducing or modifying the ground movements generated by tunnelling/box excavation

by improving or changing the engineering response of the ground. Categories of ground treatment include: compensation grouting, which involves injecting grout into the ground above the tunnel to compensate for the ground loss at the tunnel face; permeation or jet grouting which involves the creation of stiffer ground to reduce movement; and control of ground water to avoid changes which could potentially cause ground movement.

- *Structural measures.* These methods reduce the impact of ground movements by increasing the capacity of a building to resist, modify or accommodate those movements. Typical measures would include underpinning or jacking. Underpinning involves the introduction of a new strengthened foundation system to a building or structure potentially affected by settlement. Jacking is a technique whereby a system is introduced between the building and its existing foundations to compensate for any movement.

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## Preconstruction defect surveys



Defect surveys will be undertaken on all buildings predicted to be significantly affected by ground movement. This is a written and photographic record of any existing cracking and deterioration of finishes and structures carried out by a chartered building surveyor working jointly for the promoter of the works and the owner of the building.

### **Monitoring**

The need for monitoring will be determined on a case-by-case basis as part of the assessment process. Where required, monitoring will start prior to commencement of the works and continue until significant movement attributable to the works has ceased.

### **Consultation and commitment to repair**

Reasonable steps will be taken to consult the owners and occupiers of buildings that are assessed to be vulnerable to ground movement about the proposed measures to limit the damage that might occur. In the event that a building experiences damage arising from ground movement caused by tunnelling and/or deep excavations, repairs will be undertaken and the reasonable costs reimbursed by the promoter of the works as partial or full settlement of any compensation claim. Payment will be subject to prior agreement about any such repairs.

### **Provisions in relation to Listed Buildings**

Specific consideration will be given to buildings which are listed as being of special architectural or historic interest (“listed buildings”) in order to protect the building and any sensitive features or features of heritage value.

The specific mitigation measures to be used for each building will be determined during the detailed design and construction planning phases.

### **Guidelines on ground movement**

For further detailed information a copy of the full Ground Movement Guidelines is available. The paper describes in more detail the processes for assessments and the carrying out of any necessary surveys, monitoring and protective works.